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Gait Analysis and Recognition for Human Identification

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Abstract

Human gait reveals feelings, intensions and identity. Gait is used as biometric feature to identify walking individual at a distance. This paper presents an approach to identify human gait patterns using features extracted from statistical moments. Post background subtraction, silhouette frames of walking subjects were segmented into 9-segments representing different human body parts. Statistical moments, *viz.*, geometric moments, Legendre moments and Krawtchouk moments were used individually to extract some distinguishable gait features namely centroid, aspect ratio and orientation from each segment of the silhouettes. In addition to these features, height and width of the personwere also included. Each walking person was represented by a gait pattern ora feature vector, generated using 38 features extracted from silhouette.A minimum distance classifier based on Euclidean distance was used to recognize the input image sequence in testing phase. All the experiments were conducted on CASIA database.In the experimental results; it was observed that the performance of geometric moment based representation was the best among the three moments. From the proposed method, we achieved an encouraging recognition rate of 92.50% and thereby it holds immense potential in myriad of niches for prospective applications particularly in solving cases of the crime scene.

Keywords: Gait analysis, gait recognition, human identification, silhouette, gait features, feature vector, statistical moments, classifier, CASIA

1 Introduction

Gait refers to the nature of movement of the limbs of animals (including human beings) during locomotion over a solid substrate. In this context, gait can be used as a biometric to recognize a person according to the latter's classified features and verify whether the person is known or unknown. It is mostly used for detection of the people while walking and human recognition in videos in many applications, such as traffic monitoring, human motion capture and video surveillance. Gait, as a biometric feature is advantageous in certain aspects as it requires no subject contact unlike fingerprint biometric, iris scanning and so on [Nixon et. al., 1999.].In two different experiments, Stevenage et al., [1999] had shown that gait could be used as a reliable means of discriminating between individuals. Gunnar Johansson, [1975] reported that an observer can recognize person if walked with light affixed to joint of subject.

It is pertinent to note that the majority of current approaches analyse an image sequence to derive motion characteristics that are then used for recognition. We used computer vision techniques to derive a gait signature from a sequence of images. A sequence of frames of a walking subject was taken from CASIA database. This was followed by processing of the frames using different techniques to extract the distinct gait features. These were finally classified/ recognized with video stored in the database.

Our pre-processing work is similar to the work done by Lee and Grimson [2002]. In our work we used central moment, Legendre moment and Krawtchouk moment separately to extract features like centroid, aspect ratio and orientation from each silhouette images. Finally, these features were used for recognition of walking individuals.

2 Related Approaches

Gait recognition method can be implemented by thinking of what accounts for human perceptual ability and implement the perceptual ability of human into machines. Early work towards gait recognition has shown two dominant models to predict human identity. A person gait can be modelled by shaped based models and/or motion based [Yam and Nixon, 2009]. The first motion approach was examined by French physiologist and physician Étienne-Jules Marey [1884] founding father of cinematographic technique which was used to capture and display high speed moving image. Marey[1884] filmed walking subjects with small markers. Gunnar Johansson coined the term PL animation, according to him a person is able to identify subjects walking with lights affixed to their body parts. Lettvin et al. [1959] experiment in 1959 described that frog eyes inform his brain about the visual image in terms of local patters. Dittrich et al., [1993] attached thirteen small point markers to dancer's body to analyse the dancer's emotions. Troje [2002] studied gait pattern using 15 marker point attached to swimming suits of walking subject. These studies show that point light display contains enough information to reveal identity of person.

However contradictory studies shows shape based models revel better information than motion based features for classifying gait patterns. The shape based studies are used because model capture

image characterises better and can totally work irrespective of how a person moves. Pilz et al. [2006] suggested non rigid motion effect identity decision even across extended period of time and changes in viewpoint. Lee et al [2002] conducted an experiment on gait recognition by dividing the silhouette into 7 segments and an ellipse was fitted into each of the segment and features were computed to classify pattern. Human stick structure is also proposed in gait feature extraction. A 2D stick model was obtained though line fitted to the skeleton of the silhouette images by Niyogiet al. [1994]. While Cunado et al. [1997] modelled the thighs as interlinked pendula to extract their angular moment.
J. H. Yoo et al. [2005] described a gender classification system. Their gender classification system consists of three stages. To represent the gait signature that is primitive data for the feature generation based on motion parameters, they had used a sequential set of 2D stick figures. Then, they used an SVM classifier to classify gender in the gait patterns.

3 The Proposed Method

In this paper a gait recognition method was proposed for human identification. This method includes two phases: training phase and testing phase. The pre-processing work is similar to the work done by Lee et al. [2002].Our proposed system is shown in Figure.1.

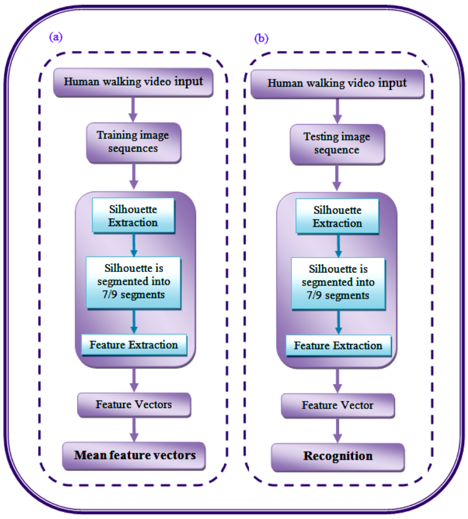

Figure1. Flowchart depicting the two phases of human gait recognition method (a) training phase; (b) testing phase

3.1 Training Phase

In the training phase, initially the equal numbers of frames were extracted from each image sequence or video of training database. The training database contains several human walking image sequences of different people.After extracting the images, all the images of each image sequence were processed through several steps of training phase of the proposed algorithm.

3.1.1 Background Removal/Silhouette Extraction

The silhouette images were extracted from the image sequences of the initial database using background subtraction algorithm.For extracting silhouette, each frame of the video sequence was subtracted from a plane background frame pixel-by-pixel. Then the subtracted intensity value of each pixel was compared with a threshold value "T". If the subtracted intensity value was less than "T", then the pixel was considered as a part of background and we assigned that pixel with a value "1" in the binary image of that frame, otherwise we assigned that pixel with a value "0". Let I(x, y) be an extracted frame, b(x, y) be the background image and 'a' be the subtracted value for each pixel which can be computed by

$$a = \left|b(x_i, y_j) - I\,(x_i, y_j)\right| \tag{1}$$

The silhouette image S(x, y) can be computed by

$$S(x_i, y_j) = \begin{cases} 1, for\ a \leq T \\ 0, for\ a > T \end{cases} \tag{2}$$

Where i, j = 1, 2, 3 ... n, are the coordinate values, T is a threshold value

The resultant binary image matrix was inverted and hence silhouette of the walking person was extracted. Sample image of extracted human silhouette is shown in Figure 2.

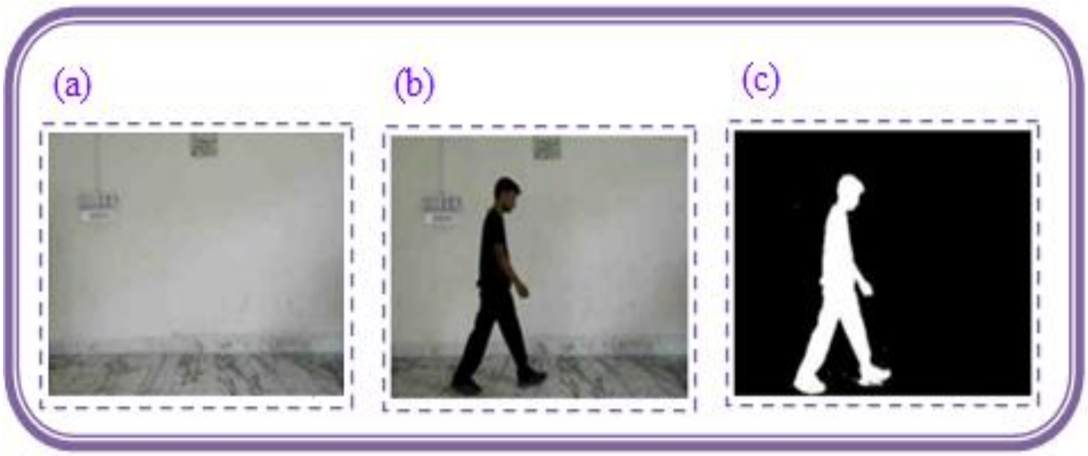

Figure 2.Silhouette extraction (a) background image; (b) original image; and(c) extracted silhouette

3.1.2 Segmentation of Silhouette

After extracting the silhouette images, the centroid was calculated for each silhouette image of the image sequence. [Mukundan and Ramakrishnan, 1998] Geometric moment was used for the computation of centroid of the silhouette using:

$$m_{pq} = \sum_p \sum_q x^p y^q f(x,y),\ p, q = 0, 1, 2, 3 \ldots \quad (3)$$

$$x_0 = m_{10}/m_{00}; y_0 = m_{01}/m_{00} \quad (4)$$

Where, m_{pq} is the geometric moment and p, q are the order of the moment, f(x, y) is the silhouette image and (x_0, y_0) is the centroid of the silhouette image.

Lee et al., [2002] divided the entire human silhouette into 7 segments in their work but in our proposed method, the human silhouette was divided into 9 regions, i.e. the torso region was divided into two parts upper torso and lower torso. After analysing many videos of different peoples of different heights and weights, the parts above and below the centroid of the silhouette were divided in the horizontal direction with some ratios (head portion, , upper torso, lower torso, thigh portion and calf portion as 19%, 20%, 20%, 20% and 21% of total height) and the vertical front and back sections, except for the head portion, resulting in 9 regions: p1, head/shoulder region; p2, upper front of torso; p3, upper back of torso; p4, lower front of torso; p5, lower back of torso; p6, front thigh; p7, back thigh; p8, calf/foot; and p9, back calf/foot. A vertical line was drawn through the centroid by assigning ‘0’ to the corresponding pixel values of the binary image except the head portion. Then, horizontal lines were drawn according to the ratios stated below. Hence, 9-segments were obtained from the human silhouette. In Figure 3, segmentation of a sample silhouette image is shown.

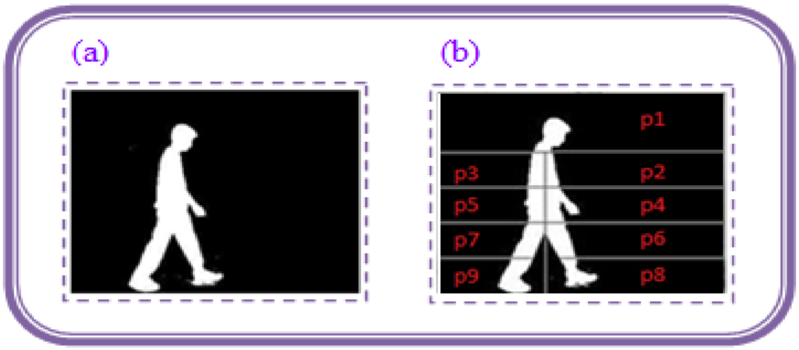

Figure 3.Segmentation of the human silhouette (a) Centroid of the silhouette, (b) 9-segments of the silhouette of a foreground walking person

3.1.2 Features Extraction

Each of the 9 segments of the silhouette was consideredas an imaginary ellipse which is also similar to the pre-processing work of Lee et al., [2002]. Statistical moments, viz., geometric moments, Legendre moments and Krawtchouk moments were used individually to extract some distinguishable gait features from each of these segments are as follows:

1) Centroid (x_i, y_i), includes 2 sub-features
2) Aspect ratio (*l*) of the major and minor axis of the ellipse, included as a feature
3) Orientation (α) of major axis of the ellipse, included as a feature

So, in total 4 features were extracted from each segment. Aspect ratio (*l*) of the major and minor axis of the ellipse, and the orientation (α) of major axis of the ellipse were obtained by using different moments and processed them separately [Mukundan and Ramakrishnan, 1998]. Each segment of a silhouette contains 4 features and each silhouette consisting of 9 segments, therefore 36 features were extracted; in addition to these 36 features the height *(h)* and width *(w)* of the person were also considered as a feature of the silhouette of the person. Hence, 38 features were extracted from one frame and these features were extracted from all the frames of an image sequence and their average was taken as the final values to obtain the feature vector. And each walking sample video is represented by the computed feature vector.

$$\text{Feature vector} = [h \quad w \quad f(r_1)\, f(r_2) \ldots\ldots \quad f(r_9)]_{1x38} \qquad (5)$$

Where, $f(r_i) = [\, x_i \;\; y_i \;\; l_i \;\; \alpha_i \,]$ is the feature vector of i^{th} segment of the silhouette of walking person and $(x_i, y_i, l_i, \alpha_i)$ are the features extracted from a segment.

All the images of each image sequence were processed through above steps of feature extraction and hence, all the feature vectors were computed for entire training database to obtain the feature matrix.

The feature matrix mathematically, can be defined as 2D matrix, where the row indicates features vector of each individual image sequence/video and column indicates the number of features. Using this Feature matrix, mean feature vector for each person was calculated and this was used as template for each person in the testing phase to verify whether the person is known or unknown and to recognize the person in the recognition phase.

$$\text{FEATURE MATRIX} = \begin{bmatrix} h_1 & w_1 & f_1(r_1) & f_1(r_2) & f_1(r_3) & f_1(r_4) \ldots\ldots\ldots . f_1(r_9) \\ h_2 & w_2 & f_2(r_1) & f_2(r_2) & f_2(r_3) & f_2(r_4) \ldots\ldots\ldots . f_2(r_9) \\ h_3 & w_3 & f_3(r_1) & f_3(r_2) & f_3(r_3) & f_3(r_4) \ldots\ldots\ldots . f_3(r_9) \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\ h_N & w_N & f_N(r_1) & f_N(r_2) & f_N(r_3) & f_N(r_4) \ldots\ldots\ldots . f_N(r_9) \end{bmatrix}_{N \times 38} \quad (6)$$

Where, h_i is the height of i^{th} person, f_i is the feature vector of i^{th} segment and N is the number of input walking samples for Training phase.

3.2 *Testing Phase*

The initial steps of training and testing phase were same. In the testing phase, an image sequence of a person was taken as input for the recognition and the silhouettes were extracted from the images. After extracting the silhouettes, from each silhouette image all the 38 gait featureswere extracted and the corresponding feature vector was computed as done in the training phase.

3.3 *Recognition*

For the recognition task a minimum distance classifier based on Euclidean distance was used. Euclidian distances of the feature vector representing the input image sequence were computed from the mean feature vectors which were generated in the training phase and the minimum Euclidean distance was compared with a threshold value. If the value was less than the threshold value then the subject was consider as known person whose image sequence were taken as sample in initial training database, otherwise person was consider as unknown person. If the person was known, then the input image sequence was classified as belonging to the person with minimum distance.

4. Experiments

All the experiments were conducted on CASIA (Institute of Automation Chinese Academy of Sciences) database. The resolution of each input image was 320X240 pixels. The image sequences of 16 persons were taken, 10 image sequences from each person. Hence, total 160 image sequences were used for the dataset of training and testing phase and each image sequence contains 50 images. All the image sequences were taken as input in form of video in the proposed method and then every image of each image sequence was processed through subsequent section in training and testing phase.

5. Discussion and Result

In the proposed method, silhouette of the human walking image sequences was extracted using background subtraction algorithm in which a threshold value is required. To set the threshold value, background subtraction was performed many times with several threshold values manually and the best result was achieved with a threshold value of "45". So, the threshold value was set to a value of "45" which is necessary in the background subtraction and hence silhouettes of the sample image sequences were extracted successfully in the propose method.

The recognition rates obtained by using different number of segments considered in silhouette partition are shown in the table I. During the design of the approach, initially 7- segment was taken for the feature extraction and compared the result with that of 9-segment. Relatively good recognition rate was achieved when the 9-segmentswere considered for silhouette segmentation.

Table I.

Result obtained by considering different number of segments

Segments	Recognition Rate
7- segments	81.25 %
9- segments	92.50 %

Table II demonstrates the recognition rates which were obtained by using different types of statistical moments (geometric moment, Legendre moment and Krawtchouk moment) for extracting features Table 2.

Table II

Recognition rates obtained by considering different statistical moment from the silhouette

Moments	Recognition Rate
Geometric moment	92.50 %
Legendre moment	78.75 %
Krawtchouk moment	69.37 %

. The experimental results demonstrate that the recognition performance of geometric moment based representation relatively good among the three moments.

6. Conclusion and Future Work

In this paper a human gait analysis and recognition method was proposed by using statistical moment. The results showed that it was effective when the geometric moment was used for extracting the features from the silhouette of the walking person. The proposed method was also tested by considering different number of segments for the segmentation of silhouette.The experimental results revealed that the recognition performance was relatively better when 9-segments were considered. The variation in the results might have been due to the relative moment in 2-extra segment compared to the other segments in 9-segment silhouette.

The change in clothing type of a person in different image sequences, used in Training/Testing phase might have affected the recognition rate. To allow more accurate recognition of a person with change in clothing requires multiple representation of the person. The work has high future prospects as it could be extended to coalesce face (as face is less susceptible to appearance change) recognition pattern or other biometric techniques with the individual-specific parameter-dependent gait information to improve the recognition performance to a greater precision.

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